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LED Technology and Smart City, their Role and Impact on Man and the Environment

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Abstract. This chapter explores the evolution of public lighting, tracing its historical development from the early days of illumination to contemporary times. It highlights the contemporary significance of public lighting in meeting regulatory standards for illumination, emphasizing the fundamental role of LED technology. LED technology not only ensures compliance with lighting regulations but also significantly reduces network power consumption, thereby mitigating environmental pollution compared to traditional discharge lamps. Furthermore, this chapter underscores the transformative shift in the role of modern lighting systems, which have evolved into multifunctional hubs for the integration of value-added services. These services encompass a wide range of applications, including surveillance cameras, smart parking systems, and electric vehicle charging stations, thereby enhancing the overall functionality and sustainability of urban environments.

Introduction

The concept of public lighting, as it is known today, may seem relatively recent, but its origins can be traced back to ancient practices where certain parts of significant structures were illuminated using torches or braziers, providing continuous nighttime illumination. However, it wasn't until later centuries that the idea of illuminating entire cities came into existence.

Two pioneering cities in this regard were London and Paris. In 1417, Sir Henry Barton, the Mayor of London, issued a directive that lanterns should be hung on winter evenings between All Saints and Candlemas, marking one of the earliest recorded instances of a city attempting public lighting. Paris followed suit with an ordinance in 1524, instructing its residents to keep lights on in their windows for the sake of public safety.

Initially, these early "lampposts" relied on various oils such as olive, fish, walnut, and even whale oil for illumination, a practice that persisted until the latter half of the eighteenth century [1]. The subsequent era saw the emergence of gas fuels, which gained popularity around 1800.

As time progressed and technology advanced, gas fuels were gradually phased out in favor of electrical lighting systems. The adoption of electricity was propelled by its ease of use, the consistency of light it offered, and the rapid advancements in the electrical industry, which made it possible to bring electric power to virtually every corner of cities [2].

With the ongoing evolution of technology, new types of lighting sources emerged, classified according to the substances responsible for emitting light radiation. Among these, incandescent lamps and LED lamps belong to the family of solid-state lighting sources, while discharge lamps fall under the category of gaseous sources [3]. These sources exhibit distinct characteristics, including differences in average operating life, color temperature, luminous efficiency, and time required to reach full brightness upon activation.

In the following sections, the chapter will delve into the complex details of the technological and environmental facets that render LED technology exceptionally attractive within the domain of public lighting.

Furthermore, it will explore how contemporary public lighting systems can be strategically leveraged to cater to the burgeoning landscape of Smart City technologies and the incorporation of value-added services. This endeavor is facilitated by their extensive deployment throughout urban landscapes, serving as a foundational infrastructure for the integration of innovative urban solutions.

Methodology and Structure

This chapter unfolds as a systematic exploration divided into three fundamental sections, each contributing to a comprehensive understanding of the subject matter:

1. Environmental context.

In this initial section, the contribution provides an in-depth overview of the prevailing environmental conditions on a global scale. By examining the broader environmental landscape, with the aim to contextualize the importance of sustainable approaches in various sectors, including public lighting.

2. Sources in public lighting: a focus on LED technology.

The second section focuses on the sources of illumination used in public lighting, delving into the various technologies employed, with particular emphasis on LED technology. This investigation reveals how LED lighting aligns with the core principles of economic, environmental, and social sustainability, making it a crucial component in the evolution of public illumination.

3. Value-added systems and beyond.

The final section expands the horizons of public lighting beyond its conventional role, exploring the integration of value-added systems within modern lighting infrastructure. This discussion highlights that public lighting is evolving beyond its traditional purpose of merely illuminating streets; it is now becoming an integral system capable of elevating cities to new heights of technological advancement, safety, and functionality.

In essence, this analysis aims to demonstrate that public lighting is undergoing a transformative shift. It is no longer limited to its historical role but is emerging as a complex system with the potential to significantly enhance urban living. By embracing sustainable technologies such as LED lighting and incorporating value-added systems, public lighting is contributing to make our cities more resilient, smart, and efficient, redefining its purpose in the modern urban landscape.

Environmental Context

The complex network of gases that accumulates in Earth's atmosphere, influencing its energy balance, is commonly referred to as “greenhouse gases”. This phenomenon is responsible for the greenhouse effect, which plays a significant role in sustaining life on our planet. Without greenhouse gases in the atmosphere, the Earth's average temperature would plummet to a frigid -18 degrees Celsius, in stark contrast to the present 15 degrees Celsius.

To understand this, it is essential to understand how the Earth interacts with incoming solar radiation. Approximately 25% of solar energy is reflected and radiated back into space, not breaching the limits of our atmosphere. About 20% of this energy is absorbed by the atmosphere during its journey towards the Earth's surface, while another 5% is reflected by surfaces such as glaciers and deserts. The remaining 50% is absorbed by our oceans and continents.

Crucially, the heat absorbed by the atmosphere is not entirely lost; instead, it is re-radiated in all directions, with a portion returning to the Earth's surface, further warming it. Greenhouse gases play a fundamental role in this process by trapping some of this heat, effectively acting as a thermal blanket. Consequently, an elevated concentration of greenhouse gases in the atmosphere contributes to a rise in the global average temperature [4].

The primary greenhouse gases of concern include carbon dioxide ($CO2$), methane ($CH4$), and nitrous oxide. While these gases occur naturally in the atmosphere in limited quantities, human activities have significantly increased their presence since the early 20th century. It is worth noting that water vapor is also present in the atmosphere, but its impact on human-induced climate change is less significant, as its absorption capacity is closely tied to temperature fluctuations [5].

Today, we are confronted with sobering statistics: there is a 66% probability that global average temperatures will surpass 1.5°C above pre-industrial levels between 2023 and 2027. These five years are expected to be the warmest on record, with a 98% certainty, underscoring the cumulative effects of global warming [6].

The factors contributing to climate change are multifaceted, originating from a multitude of human activities. These include extensive deforestation, intensive livestock farming, and the application of specific fertilizers and other gases. Of particular significance is the release of greenhouse gases, including carbon dioxide and methane, which exerts a substantial influence on the acceleration of global warming.

A mere 5% of power plants across the globe bear the weight of responsibility for nearly three-quarters (73%) of the CO2 emissions produced from electricity generation on a global scale. These startling findings emerged from a comprehensive study conducted by a team from the University of Colorado Boulder, led by sociology professor Don Grant, member of the university's Renewable and Sustainable Energy Institute [7].

These findings make it clear the profound impact that reduced energy consumption can have on environmental preservation by curbing carbon dioxide emissions.

When we think about energy-intensive systems, one that immediately comes to mind is public lighting. Public lighting systems are prevalent in urban and suburban areas, and their daily energy consumption is influenced by several critical factors. The number of installed lamps, the duration of their operation each day, the level of regulation applied, and the type of light source and technology employed all play a significant role in determining energy consumption. These systems are a substantial contributor to overall energy usage in many regions, playing a pivotal role in promoting environmental sustainability and energy conservation, especially within the broader context of Smart City technologies.

For the purpose of energy analysis, the following parameters are considered:

The conversion factor for calculating consumption, expressed in tons of oil equivalent (TOE), is 0.187 x 10-3 TOE/kWh (Refer to Resolution EEN 3/08 of the Authority for Electricity and Gas, dated 28 March 2008).

For calculating CO2 emissions, the coefficient is 258.3 g CO2/kWh (0.258 x 10-3 tCO2/kWhel), as indicated by ISPRA in the document “Indicators of efficiency and decarbonization of the national energy system and the electricity sector”, Report 343/2021, Table 2.25, labeled “Emission factors of national electricity production and electricity consumption (g CO2/kWh)”, under the “Electricity consumption” column.

Sources in public lighting: a focus on LED technology

The efficiency of a lamp is defined as the ratio between the flux emitted by the lamp and the power absorbed. Therefore, as the flux increases and the power decreases, the result will be to obtain a higher efficiency of the lamp.

Below is a comparison between oil lamps, light bulb lamps, fluorescent lamps, and LEDs [8].
The difference that exists between these sources does not only concern the aspect relating to efficiency but also that relating to the duration of the source, the color temperature, and the directionality of the luminous flux.

The table below illustrates the sources used for lighting fixtures and are arranged in increasing order of useful life. The table also shows the efficiency, color temperature, CRI and lamp burn time. LED technology has the longest useful life, one of the greatest efficiencies, the possibility of choosing between different color temperatures, a CRI that can reach very high values, it is directional and instantaneous ignition [9].

Therefore, it turned out to be very advantageous from different points of view to choose a LED technology.

As highlighted in the previous paragraph, to try to mitigate the anthropic phenomena that cause the emission of greenhouse gases, it is important to reduce the quantity of pollutants dispersed in the air. Hence, being able to obtain adequate levels of street lighting, with a given flow and reducing the power absorbed by the network is essential.

Furthermore, the definition of the lighting project applied to the peculiarities of the territorial context must be carried out by punctually defining the aesthetic typologies and the characteristics of the lighting fixtures which must be suitable for each single street or square. This is to ensure design quality also from an aesthetic point of view as well as from an environmental point of view.

In fact, it is possible to identify different types of lighting fixtures, with different aesthetic shapes. There are multiple solutions that aim to enhance each territorial context. Every consideration that underlies every single project must be examined for perfect harmony with the existing urban planning, also considering the architectural constraints.

The interventions that must be foreseen within a public lighting system redevelopment project must therefore be defined in compliance with the state of the places and must include solutions aimed at fitting into the specific urban area concerned.

It must be ensured that there is no negative impact on the environment in any way. On the contrary, the aim of the project must be to reduce direct glare, to improve the quality of light, to guarantee control of the luminous flux in terms of directionality and quantity of light emitted and therefore to minimize the dispersion of light towards areas different from the work plan.

Lamp technology	Efficacy [lm/W]	Life time [hours]	CRI	Available dimming Level [%]	Dimming Influence	Startup time
Incand.	10-17	1k	100	100	Positive: Lifetime extending	Instantly
Halogen	12-20	2k	100	100	Negative: Lifetime shorten - halogen cycle doesn't work	Instantly
FL	20-60	10-20k	80	10	Neutral	1-5 sek
MV	25-40	14-20k	80	50	Negative: Lifetime shorten - Coor shifting	5-7 minutes
MH	35-50	10.15k	60-90	50	Negative: Lifetime shorten - Coor shifting	2-5 minutes
HPS	55-65	24-32k	40	80	Positive: Lifetime extending	5-10 minutes
LED	65-75	50-100k	70-90	100	Positive: Efficacy risen, Lifetime extending	Instantly

Fig. 1. Comparison of light sources performance [3]

CLO technology

CLO, which stands for Constant Light Output [10], represents an ingenious system devised to counteract the natural decline in luminous flux that occurs over time, as well as to prevent excessive brightness during the initial stages of luminaire operation.

As lighting sources age, their luminous flux tends to diminish due to various factors, including the accumulation of dirt on the cover glass. The innovative CLO system, however, offers a solution by ensuring a consistent flux output from the source throughout its operational life. The underlying principle involves running the fixture at a lower current during its initial stages and gradually increasing it over time, thereby maintaining a constant flux.

This technology provides a multitude of benefits. It ensures a uniform level of illumination over an extended period, thus guaranteeing the long-term performance and longevity of the LED module. Even, it results in reduced power consumption from the electrical grid, leading to significant economic savings and substantial environmental advantages.

Operating the luminaire at lower power levels also contributes to reducing CO_2 emissions and lowers TOE (tons of oil equivalent) consumption, with a positive impact on the environment [11].

Switchable white light

To ensure nighttime urban safety, it is necessary and essential for inhabited areas to be equipped with artificial lighting. However, artificial lighting could pose a threat to ecosystems. In fact, both fauna and flora are strongly influenced by the natural alternation of light and dark, as this cycle regulates and governs vital behaviors: nourishment, reproduction, sleep-wake rhythm, and protection from predators. [12]

Therefore, when designing a public lighting system it is essential to take the environmental aspect into consideration from various points of view: ensuring that the streets are safe for pedestrians and vehicles; minimizing environmental pollution by using light sources that are as efficient as possible; preserving the environment by protecting local fauna and flora by installing lighting systems only where strictly necessary.

According to some studies, blue light appears to be harmful to ecosystems as unfortunately, it produces high levels of light pollution, and has a significant environmental impact. This type of light increases glare and compromises human vision; this especially concerns the eyes of the elderly. Light using short wavelengths also disproportionately increases skyglow. In addition, blue light has an increased tendency to affect living organisms by disrupting biological processes that rely on natural cycles of light and dark, such as the circadian rhythm. A modest improvement in the efficiency of outdoor lighting dramatically increases the environmental damage caused by artificial light.

Human visual sensitivity is mostly concentrated in the green and yellow parts of the spectrum. The color of the light emitted by the first LEDs was typically bluish (5,500 Kelvin), but now, with technological progress, there are sources with very warm color temperatures [13].

Indeed, some manufacturers of LED lighting fixtures have developed systems that allow you to program the lighting fixture by changing the color temperature during the evening and at night based on the effect you intend to achieve.

Some are designed for the integration of timers, remote control devices, or sensors for detecting the external environment, useful for reducing the intensity of the light in conditions of low traffic or good visibility. Other products allow you to alternate a very warm light with reduced blue content (CCT = 1800 K), which protects flora and fauna, to a warm light with moderate blue content (CCT = 3000 K), which improves human visual performance when traffic is heaviest [14].

Discussion

Value-added systems and beyond

Remote control and smart city. There are technological systems that allow public lighting systems to be controlled remotely.

Remote control systems can be divided into two macro-categories: switchboard or “stand-alone” remote control systems and point-to-point remote control systems.

Both have the function of remotely controlling and managing the public lighting system. The purposes are multiple and concern the monitoring and management of the single luminaire: it is possible to detect any malfunctions of the system; it is possible to monitor energy consumption; it is possible to manage any faults directly remotely; and it is possible to regulate the flow of the luminaires up to the point of commanding their shutdown. The substantial difference between the two systems lies in the fact that the standalone remote control requires the installation of a panel device that allows remote management of the entire circuit to which the lighting complexes belong.

The point-to-point remote control also provides for the installation of a node on the single fixture, which allows the remote management of the single light point, which can therefore be controlled and managed remotely independently of the other lighting fixtures that are subject to the circuit.

Installing point-to-point remote control in the centers of greater aggregation can be a plus because, in organizing events such as open-air cinema, it is necessary to switch off the lighting systems that interfere with the projections for a specific time.

This operation in a non-telemanaged system can only be carried out by physically modifying the circuit and installing dedicated timer clocks. On the other hand, with point-to-point remote control, it is possible to regulate the flow of a single device, regardless of the shape of the line, up to total shutdown without making physical changes to the lines, directly remotely. This makes it possible to considerably reduce intervention times and costs and considerably simplify the operations to be carried out on the system.

Furthermore, point-to-point remote control can be easily implemented for the creation of adaptive lighting, which allows automatic regulation of lighting based on the presence or absence of users, thanks to the simple installation of detection systems. This system guarantees the most suitable lighting in real time and saves further energy and related costs, reducing waste and emissions while still providing an efficient and reliable service.

With “adaptive public lighting”, we mean those innovative solutions capable of redeveloping and enhancing cities, making them increasingly comfortable, intelligent, and economically, socially, and environmentally sustainable. The goal is to offer a valuable service to citizens: providing the right amount of light in the right place and at the right time allows you to reduce waste and rightly save the environment; always having safety first (keeping high visibility at night); and the enhancement and redevelopment of urban spaces [15].

The remote-control systems allow operators to monitor consumption and any operating anomalies that may arise. It is interesting to underline that the traffic management service (adaptive traffic control) can be implemented on these systems with the aim of making the roads and, consequently, travel safer. It is possible to distinguish between TAI and FAI.

TAI is the acronym for Traffic Adaptive Installation, in which the operating lighting category is chosen based on sampling the hourly traffic flow only. This is a step forward compared to the existing situation in which the luminous flux is reduced at a given hour based on traffic statistics, but in any case, it is linked to the lighting engineering categories and their variation steps. To operate this regulation, a traffic meter is sufficient for each lane, and based on the sampling of the same, an algorithm raises or lowers the operating lighting category.

FAI stands for Full Adaptive Installation. In this case, both a traffic sensor and a lane luminance sen sor are required, which allow you to sample the luminance of the road surface or the illuminance and the weather conditions and then act accordingly. In this case, the real difference is the overcoming of the barrier of the plastered lighting categories because, at any moment, there is perfect knowledge of the operating parameters, and depending on the weather conditions, the system can be made to react. The FAI solution is the first real technological step forward in lighting (next and future) that the champions of eco-sustainable lighting have been waiting for several years now [16].

Analyzing a case study, 90 remote control devices and two environmental sensors were installed in the Municipality of Rimini to collect updated and reliable information. IoT systems empower the comprehensive collection of data pertaining to various aspects of road infrastructure. This includes functions such as monitoring the ambient lighting conditions on the road surface, capturing the luminous flux emitted by individual light points, recording traffic volume, measuring noise levels, and tracking the inclination of the poles supporting each light point.

Additionally, these systems facilitate continuous air quality monitoring through the deployment of a specialized control unit equipped with cutting-edge electrochemical sensors. These sensors make it possible for the real-time detection and quantification of four distinct gas types, such as carbon monoxide (CO), nitrogen oxide (NO), nitrogen dioxide (NO2), and ozone (O3), leveraging innovative experimental technology to ensure precise and continuous air quality assessment.

Overall, the implementation of control systems for public lighting on busy main roads has achieved a remarkable 30% reduction in energy consumption. Simultaneously, these systems enable continuous data collection and the analysis of statistical information regarding hourly and daily traffic conditions as well as vehicle types. This invaluable data serves as the foundation for the development of innovative strategies aimed at curbing urban pollution [15].

The original function of the street lighting pole, of course, was to support one or more lighting fixtures. In a medium-sized city, there are thousands of street lighting poles. In Italy, municipalities own at least 7 million of the estimated 9 million lighting poles. Inherently, the public lighting electricity network is estimated at around 270,000 km.

With the remote management of the lighting systems through the luminaire, pole, and electricity grid systems and taking advantage of the strong widespread presence of the systems within the territories, it was possible to: receive alarms and electrical measurements; command switching on and off; remotely adjust the flow of centralized or punctual lighting; and better plan management and maintenance through remote diagnostics.

Therefore, taking advantage of the strong presence of the systems in the area, the intention is to expand the services offered to the citizenry, which do not only concern lighting but also weather conditions, environmental analyses, traffic situations, and critical situations such as accidents, weather alerts, emergencies, etc. It is also possible to install video surveillance cameras, parking sensors, or pole charging systems on the poles [17].

The project of electric recharging from light poles led to the creation of 800 recharging points in Berlin. The light poles use Ubitricity's “Heinz” charger, which was specially developed for the German market.

The existing infrastructure is exploited to allow citizens who do not have private parking (about 60% of drivers) to recharge their cars comfortably close to home. For this reason, the project only takes residential areas into consideration, considering the capacities of the existing network [18].

Charging of electric cars from poles. The electric recharging project utilizing light poles has resulted in the establishment of 800 recharging points in Berlin. These light poles are equipped with ubitricity's specialized “Heinz” charger, designed specifically for the German market.

This initiative strategically leverages existing infrastructure to provide convenient car recharging options for citizens residing in areas without private parking facilities, a demographic comprising approximately 60% of drivers. Accordingly, the project focuses exclusively on residential areas, taking into account the capacity of the existing network [18].

Accessing charging stations within the city can sometimes pose challenges, as the number of such stations, while steadily increasing, still falls short of meeting the growing demand. In this context, the collaboration between Siemens and Ubitricity, with the support of Westminster city council, is particularly noteworthy. This partnership has transformed 24 streetlamps along London's Sutherland Avenue into charging points compatible with the Type 2 standard, offering power ranging from 3 to 22 kW in direct current.

The concept of implementing such pole charging systems in urban environments carries numerous advantages and benefits. These lighting complexes can serve the dual purpose of illuminating streets and facilitating the recharging of electric or hybrid vehicles.

Consequently, the widespread adoption of these systems could incentivize the population to invest in electric cars, particularly in regions facing a shortage of dedicated recharging columns. Moreover, owners of electric or hybrid vehicles may be encouraged to choose holiday destinations where recharging infrastructure is readily available.

Smart Parking. Smart parking, an innovative approach to optimizing parking, has garnered considerable attention as an integral component of the broader Smart City concept.

It stands at the crossroads of technology and innovation, aiming to streamline the often chaotic and time-consuming process of finding and securing parking spaces while delivering substantial economic and environmental benefits to urban environments.

Smart parking systems operate through continuous monitoring of parking space availability, occupancy status, and vehicle stay durations.

This monitoring relies on sophisticated algorithms driven by computer vision and deep learning, which analyze images captured by strategically placed cameras or sensors. Remarkably, these systems maintain an accuracy rate exceeding 99%, even in adverse weather conditions, making them highly reliable.

The process begins with images being captured by standard cameras and transmitted to a central server. Flexibility exists to determine the intervals at which this image processing occurs. Alternatively, employing cameras with integrated embedded PCs, such as the LTM sensor, enables on-site data processing. Subsequently, data is transmitted to the electrical panel via the existing narrowband network within the public lighting infrastructure and then forwarded to the server through a broadband device.

The single-camera coverage capacity varies based on parking area layouts, typically encompassing 20 to 30 parking spaces. To monitor larger areas effectively, additional modules can be installed. These systems offer real-time data, forecasting capabilities, and the identification of vehicles parked in unauthorized zones.

One of the most apparent advantages of smart parking systems is their ability to alleviate traffic congestion. By efficiently directing drivers to available parking spaces, these systems reduce the time spent searching for parking, thus decreasing traffic congestion and associated emissions. This not only benefits drivers but also contributes to a cleaner and more sustainable urban environment.

Beyond traffic reduction, smart parking systems yield economic and environmental advantages. Drivers expend less fuel and time searching for parking, resulting in reduced fuel consumption and lower greenhouse gas emissions. Additionally, these systems minimize idling time, leading to reductions in air and noise pollution and ultimately enhancing urban air quality and residents' quality of life.

From a financial perspective, smart parking systems offer revenue-generation potential for municipalities. They enable efficient parking management through mechanisms like parking fees and fines, increasing municipal revenue streams. Moreover, maintenance costs associated with traditional parking infrastructure, such as parking meters, are substantially reduced.

For citizens, smart parking translates into cost savings. Lower fuel consumption reduces expenses, and less time spent searching for parking enhances convenience. The time saved can be redirected toward more productive activities, enhancing the overall urban experience.

Smart parking solutions are not one-size-fits-all; they can be adapted to meet the different needs of various urban environments. In residential areas, these systems assist residents in finding parking near their homes conveniently, alleviating the stress of hunting for a parking spot after a long day. Commercial areas benefit from optimized parking solutions that cater to shoppers and tourists, driving local businesses and tourism.

Beyond immediate advantages, the implementation of smart parking systems aligns with the strategic goals of cities aspiring to become smart cities. These systems contribute to data collection and analysis, providing insights into traffic patterns, parking utilization, and urban mobility. Such data informs city planning and infrastructure development, leading to more efficient urban designs and transportation systems.

In conclusion, smart parking systems represent a significant step forward in urban mobility and sustainability. Their ability to reduce traffic congestion, emissions, and stress while increasing convenience for residents and visitors alike makes them a valuable addition to cities worldwide. As urbanization continues to expand, the adoption of smart parking solutions becomes increasingly critical for creating more livable, efficient, and environmentally friendly urban environments.[19]

Findings and Conclusions

In light of the significance to mitigate greenhouse gas emissions and avoid disruptions to the global climate, it becomes imperative to conceive systems that ensure comfort while concurrently upholding environmental preservation.

For this reason, it is necessary to think about all those energy-intensive and inefficient systems that are widely spread across the territory, such as public lighting systems, to carry out a global redevelopment. To do this, it is possible to use LED technology, which allows us to ascertain energy savings that are a function of what is installed.

LEDs are considered the most efficient sources as they can convert over 50 percent more electrical power (watts) into light (lumens) compared to sodium lamps, thus significantly lowering both the cost and consumption of energy. electric energy. Utilizing these systems results in economic, energy, and environmental savings, as they draw less power from the network compared to high-pressure sodium, low-pressure sodium, or even mercury sources while emitting the same light output.

Additionally, the LED plate offers several advantages, including instant activation, long-lasting performance, adjustable color temperature to suit specific project requirements, and precise directional control, ensuring the light is focused precisely where needed, such as on the street in the case of street lighting. Therefore, there are no components that are directed towards the celestial vault, and this allows, in addition to saving energy by avoiding unnecessary waste, not to create light pollution.

In this way, it is possible to avoid the unnecessary alteration of the natural nocturnal ambient lighting and therefore “any direct radiation of light outside the areas to which it is functionally dedicated, and in particular towards the celestial vault”.

Moreover, this innovative technology exhibits remarkable versatility. It enables the adjustment of LED lamp output by a specified percentage during nighttime, and this can be achieved through autonomous systems or remote control, either across the entire network from a central panel or individually for each lighting fixture via point-to-point remote control.

Since point-to-point remote control can be easily implemented for the creation of adaptive lighting, it is possible to obtain further energy savings as this system allows the automatic adjustment of the lighting based on the presence or absence of users, thanks only to the installation of system detection. This system guarantees the most suitable lighting in real time and allows you to save further energy and related costs, reducing waste and emissions while still providing an efficient and reliable service.

By “adaptive public lighting,” we mean those innovative solutions capable of redeveloping and enhancing cities, making them increasingly comfortable, intelligent, and economically, socially, and environmentally sustainable. The objective is to offer a valuable service to citizens: providing the right amount of light in the right place and at the right time allows us to reduce waste and safeguard the environment, always putting safety first (keeping visibility at night), and enhancing and redeveloping urban spaces.

A public lighting fixture with an LED source can be equipped with a CLO system (constant light output). This system, created to compensate for the depreciation of the luminous flux over time, prevents excessive lighting from occurring at the beginning of the useful life of the lighting fixture's installation and insufficient lighting at the end of the useful life of the lighting fixture's installation. lighting fixture.

Remote control systems allow operators to monitor consumption and any operating anomalies that may occur remotely and to intervene in the field only if necessary. It is interesting to underline that the traffic management service can be implemented on these systems with the aim of making the roads and, consequently, travel with the TAI or FAI systems safe.

The Traffic Adaptive Installation simplifies luminous flux adjustments. Equipping the public lighting system with a traffic meter for each lane allows an algorithm to modulate the operating lighting category based on the collected traffic data.

With full adaptive installation, however, both a traffic sensor and a luminance sensor per lane are required, which allows you to sample the luminance of the road surface or the illuminance and weather conditions and therefore act accordingly. The FAI solution is the first real technological step forward in lighting that the champions of eco-sustainable lighting have been waiting for for several years now.

In recent years, lighting solutions have played an essential role in the transformation of cities into smart cities. This process will continue in the coming years, supported by the increasingly widespread availability of wireless connection systems and industrial Internet of Things (IoT) devices, which represent two key elements in most smart city strategies around the world.

Furthermore, taking advantage of the capillarity of the lighting systems present in the territories, it is also possible to exploit these systems for the installation of surveillance cameras, wi-fi systems, smart parking systems, and pole charging systems for electric cars.

The lighting complexes would be used not only to illuminate the road but also, for example, to charge electric or hybrid cars. This would encourage the population to purchase electric cars. In many countries, in fact, there is a shortage of columns dedicated to charging electric or hybrid cars, resulting in a reduction in the level of emissions of pollutants concentrated in cities.

Smart parking systems, combining technology and innovation, would make it easier to find a parking space, therefore reducing emissions of pollutants but also bringing benefits in terms of time and space. This would therefore be an advantage both from the citizen's point of view and from the point of view of the public administration for monitoring car parking in the city.

Public lighting will therefore no longer have the sole purpose of making the streets illuminated but will be a system that can be exploited to make cities more technologically advanced, safe, and functional.

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